My true face: unmasking one’s own face representation

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Running tittle: Metric representation of the face.

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ABSTRACT

Face recognition has been the focus of multiple studies, but little is still known on how we represent the structure of one's own face. Most of the studies have focused on the topic of visual and haptic face recognition, but the metric representation of different features of one's own face is relatively unknown. We investigated the metric representation of the face in young adults by developing a proprioceptive pointing task to locate face landmarks in the first-person perspective. Our data revealed a large overestimation of width for all face features which resembles, in part, the size in somatosensory cortical representation. In contrast, face length was compartmentalised in two different regions: upper (underestimated) and bottom (overestimated); indicating size differences possibly due to functionality. We also identified shifts of the location judgments, with all face areas perceived closer to the body than they really were, due to a potential influence of the self-frame of reference. More importantly, the representation of the face appeared asymmetrical, with an overrepresentation of right side of the face, due to the influence of lateralization biases for strong right-handers. We suggest that these effects may be due to functionality influences and experience that affect the construction of face structural representation, going beyond the parallel of the somatosensory homunculus.

KEYWORDS: face representation, self-face perception, body representation, body model, size distortions, proprioceptive pointing.

1. INTRODUCTION

The face represents one of the most social parts of our body, it is our presentation to the world and how others remember us. The face defines us more than any other body part, and is involved in important and complex functions, such as eye-hand coordination, eating or speaking. The face is instrumental to create a sense of self, and to construct our identity (Tsakiris, 2008). Threats to face integrity cause severe loss of the sense of identity, such as after face disfigurement (Callahan, 2005). Despite this, self-face representation is not static and is susceptible to representational plasticity and multisensory influences. This plasticity is an adaptive quality to maintain a coherent sense of self despite the subtle physical changes that faces experience with the passage of time (Felisberti & Musholt, 2014; Walton & Hills, 2012). Representational plasticity is also a shared characteristic with other body areas. For instance, the hands are susceptible to modulation of sensory information as the effects of extensive practice (e.g.,Cocchini, Galligan, Mora, & Kuhn, 2018; Cavina-Pratesi, Kuhn, Ietswaart, & da Milner, 2011), which may reflect functional-anatomical modifications of underlying regions of the brain (e.g., Burton, Sinclair, & McLaren, 2004; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). Self-face representation is also linked to attractiveness criteria, with a preference for having larger eyes and small nose, and self-esteem (Felisberti & Musholt, 2014).

The representation of the body and in particular, of the hands, has been widely studied, highlighting the importance of the different multisensory influences to construct a coherent representation. In contrast, face research has been predominantly focused on face recognition across sensory modalities (Casey & Newell, 2005), whilst few attempts have been made to study the underlying body model as per other body parts. In previous studies, there is a predominant use of depictive tasks that rely on visual information, for example, pointing to different locations for size estimation on a computer screen (Fuentes, Runa, Blanco, Orvalho, & Haggard, 2013), drawing the head's outline (Bianchi, Savardi, & Bertamini, 2008) or using visual estimation tasks (D'Amour & Harris, 2017; Felisberti & Musholt, 2014; Linkenauger et al., 2015). In general, the representation of the face is distorted, showing a tendency to overestimate width and underestimate length (D'Amour & Harris, 2017; Fuentes et al., 2013; Linkenauger et al., 2015). However, it is not clear that these techniques capture the representation of one's own face specifically, and not another's face. Studies using tactile information have also shown a pattern of distortions on the forehead similar to the hand when using the two-point discrimination task, as both skin areas have similar acuity (Miller, Longo, & Saygin, 2016). Another study, using participants' face pictures, in a forced-choice paradigm, showed a tendency to perceive the nose size less accurately than the size of the mouth or of the eyes (Felisberti & Musholt, 2014). Whilst these do capture how one's own body is represented, they do not capture a pure structural representation (Longo & Haggard, 2010, 2012) within personal space. Thus, there remains an important gap in understanding how one's own face is represented.

With this in mind, we designed an experiment to assess the influence of proprioception in the metric representation of the face by pointing in first-person perspective: that is, pointing *towards* one's own face. We aimed to examine size judgements for different face features by developing a novel version of the localisation task, which enables us to discern the metric representation of the face within personal space.

Previous studies on structural representation have suggested an influence of somatosensory representation on size perception (e.g. Longo, Azañón, & Haggard, 2010), and it has been proposed that the somatosensory homunculus may provide the base system from which an implicit body model is based. Facial features occupy differently-sized areas in the somatosensory homunculus, with the mouth and tongue area overrepresented (McCormack, 2014). If it is true that homuncular size representation influences perceived size of the body part, highly represented features will be perceived as bigger. Thus, we hypothesized a distorted representation of face features, with an overestimation of areas such as the mouth, compared to the nose. Additionally, different face portions have different mobility, which may affect body size perception. Previous studies have shown overestimation of highly movable body parts, such as the ankle (Stone, Keizer, & Dijkerman, 2018) and wrists (Longo, 2017), and a compartmentalised representation of upper and lower face regions (Fuentes et al., 2013). Thus, we sought to study size differences between the representation of top (eyes) and bottom (mouth) face areas anticipating overestimation for areas whose movement tends to change shape and size to a much greater extent (bottom). Lastly, we analysed the possible spatial shift that underlies the aforementioned distortions of face representation. Studies have shown a tendency to overestimate the right side of the body for right handers (Hach & Schütz-Bosbach, 2010), and this may be a characteristic also shared by the face. For this, we calculated the horizontal and vertical shifts in pointing judgements, to consider the symmetry of these judgements.

2. METHODS AND PROCEDURE

2.1 Participants

An a priori power analysis for one sample t-test with an effect size of 0.8, α of 0.05, and power of 0.8 was carried out to set the sample size in G* Power (Faul, Erdfelder, Buchner, & Lang, 2009). Previous studies on body representation have used one sample t-test for the localisation task, reporting average effect sizes of 0.8 for finger lengths (i.e., Ganea & Longo, 2017). The power analysis indicated the adequate sample size would be of 15.

Seventeen participants (10 females and 7 males) between 19 and 39 years of age (M = 24.67; SD = 5.39) were recruited. On average, participants had 16.5 years of formal education (SD = 1.2).

Handedness was assessed with the Oldfield Questionnaire (Oldfield, 1971), on which scores range is from -1 to 1. Scores below -0.5 indicate left-handedness; scores over +0.5 indicate right-handedness and scores between -0.5 and +0.5 indicate ambidextrosity. All participants but one (score = 0.36) were considered right-handed (M = 0.90; SD = 0.11; range -1 to +1).

The study was approved by the Goldsmiths Research Committee and it was carried out in accordance with the Declaration of Helsinki (BMJ 1991; 302: 1194). All participants gave written consent.

2.2 Face apparatus and procedure

Participants were comfortably sat in front of a table. A vertical acrylic sheet (30 x 30 cm) resting on two metal posts (20 cm of height) was placed in front of them. A chin rest was positioned on the edge of the table, between the participant and the acrylic sheet. To take into consideration the curved shape of the face introducing some lateral distortion, the face was positioned very close to the acrylic setting (1 cm from the tip of the nose).

A Nikon D3200 camera (single-lens reflex digital camera, 24.2 megapixels, 18 – 55 mm VR lens, 1.5x FOV crop, 23.2 x 15.4 mm DX-format CMOS APS sensor) was positioned on a tripod in front of the sheet at 90 cm from it. The camera focus was exactly on the centre of it, and camera lens was set at 18mm. Attached to the sheet there were two measuring tapes, one along the left edge and another along the top edge, to facilitate conversion of pixels into centimetres for later analyses (See Fig. 1A).

A small black dot (1-2 mm of diameter) was drawn on participants' right index fingernail as reference for later analysis of pointing responses. Participants were asked to position their head on the chin rest so that the tip of the nose was aligned with the camera focus. They had to remain silent and avoid any movement of the face for the entire experiment. Following a pilot study and previous literature (Fuentes et al., 2013; Linkenauger et al., 2015) we identified 11 unambiguous face landmarks (i.e., hairline, corners of each eye, tip of nose, lateral side of both nostrils, corners of the mouth and chin) to be located (See Fig. 1B). Then, they were asked to close their eyes and imagine the landmarks on the acrylic sheet as if they were projected in a straight line. Then they were asked to point on the acrylic sheet with their right index finger to the different landmarks read aloud, one at a time, in random order and counterbalanced across participants. The task was repeated six times for a total of 66 trials per participant.

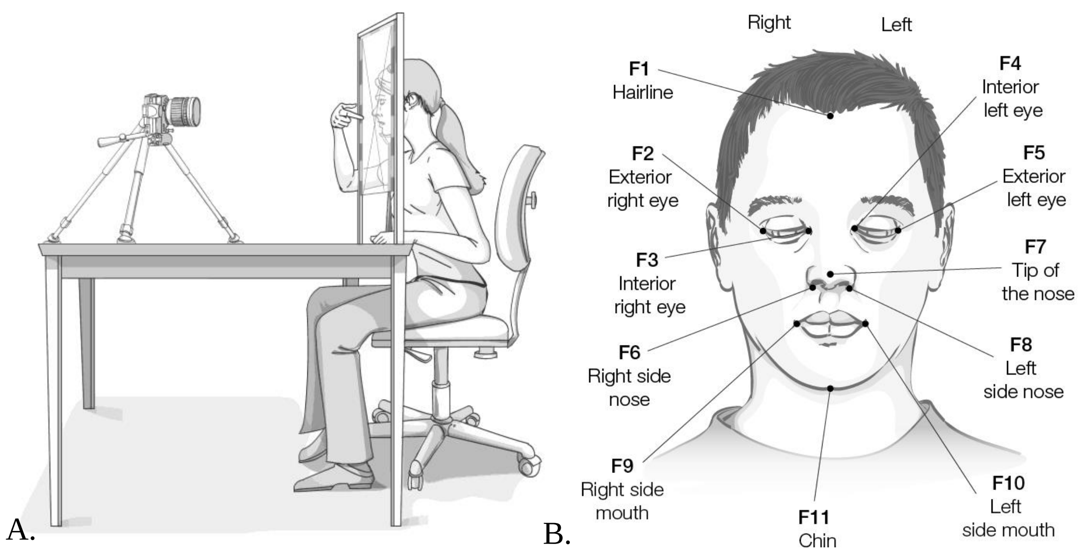

Fig. 1. Face apparatus (A) and face landmarks (B).

To ensure participants understood the labels given to the different landmarks of the face, they were asked to identify these landmarks on a schematic picture placed in front of them.

Pointing corrections were allowed to adjust the position of the right index finger, as ballistic pointing tends to be highly variable (Kammers, de Vignemont, Verhagen, & Dijkerman, 2009; Króliczak, Heard, Goodale, & Gregory, 2006). A picture was taken (6016×4000 pixels) of each response for later coding. Following this, the participant was asked to place their right index finger back on the right side of the table and wait for the next command. Feedback was not given at any time.

3. RESULTS

3.1 General analyses

A total of 66 pictures (6 for each of the 11 landmarks) were collected for each participant. An image analysis program was developed *ad-hoc* for this study using Borland C++ Builder (2007). This program converted pixel units into centimetres. Responses are expressed as x and y coordinates, with the origin at the left top corner of each picture. For each pointing response, the x and y coordinates of the real and the perceived location were collected. Data was averaged across the 6 attempts at each landmark. Following this, the distance between two landmarks (e.g., F2 and F3, See Fig. 1B) was considered to calculate length and width (in cm) of the different face features (i.e., nose, eyes, mouth); which were then averaged across the recruited participants. These data were then used to i) to analyse the shift of perceived landmarks compared to real position; ii) to analyse face length and width of its features; and finally, iii) create schematic map of real and perceived faces.

3.2 Perceived shift of landmarks

To explore the possible displacements (shift) of landmarks, we calculated the mean perceived shift (cm) per landmark. Vertical shift was the y-axis difference between perceived and real y-coordinates; a positive value indicated the landmark was perceived higher than real location, whilst a negative value indicated the landmark was perceived lower than real location, towards the body. Horizontal shift was the x-axis difference between perceived and real coordinates; a positive value indicated a rightward shift. Averaged coordinates for x and y axes between the 17 participants were used for analyses and to produce pictorial representations of real and perceived face sizes (Fig. 2A).

Perceived and real conditions were compared for each feature by means of a one sample t-test (Bonferroni corrected $p < .01$). When considering vertical shift, all areas were perceived to be significantly lower (closer to the trunk) than their real location (right eye [$t(16) = -6.34$, $p = .001$, $d = 1.53$]; left eye [$t(16) = -4.7$, $p = .001$, $d = 1.14$]; nose [$t(16) = -3.36$, $p = .004$, $d = 0.82$]; mouth [$t(16) = -6.44$, $p = .001$, $d = 1.56$] and other areas (hairline and chin) [$t(16) = -3.93$, $p = .001$, $d = 0.95$].

For the horizontal shift, all face areas were perceived shifted further to the right than the real position, with the exception of the left eye (See Fig. 2C). However, only the right eye showed a significant rightward shift [$t(16) = 5.38$, $p = .001$, $d = 1.3$].

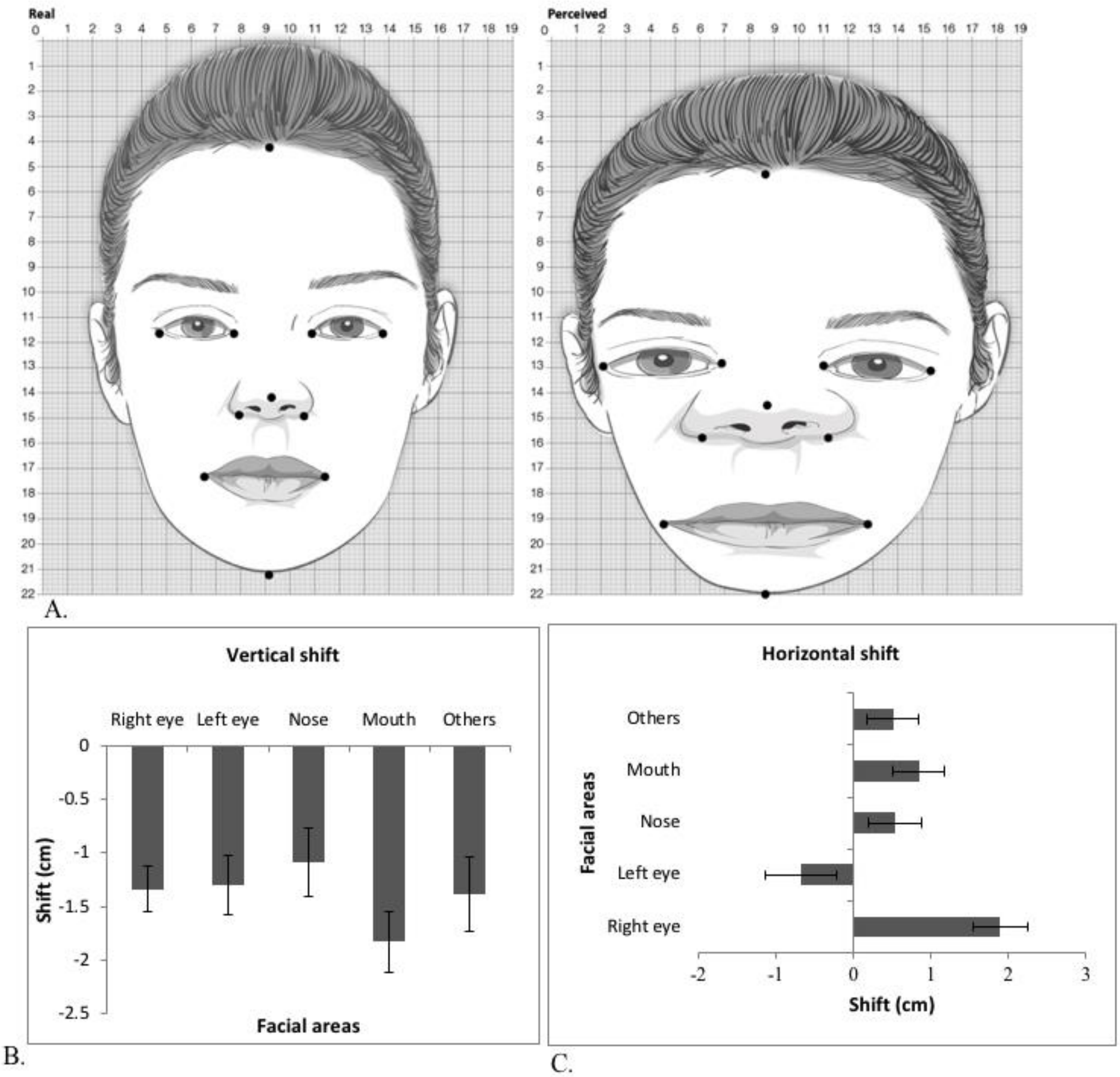

Fig. 2 Face real and perceived pictorial representation (A), face vertical shift (B), and horizontal shift (C).

3.3 Face length

Distance judgments were implicitly calculated from the localisation of landmarks as in previous studies (e.g., Longo & Haggard, 2011). The real and perceived length of three distances were considered: i) Overall face length (i.e., from hairline F1 to chin F11; See Fig. 1B), ii) Top-half (i.e., from hairline F1 to tip of the nose F7); iii) Bottom-half (i.e., from tip of the nose F7 to chin F11). These distances were averaged across all participants.

Comparison of the real and the perceived distances provided information about participants' over and underestimation. The overall face length was slightly underestimated (M = -1.62%; SD = 9.55), but not significantly so [t (16) = 0.759, p = .46; d = 0.18]. When considering different halves of the face, we found the top half of the face was significantly underestimated (M = - 6.81%, SD = 12.47), [t (16) = 2.373; p = .03; d = 0.58]. The bottom half showed overestimation (M = 6.60%, SD = 17.74) but this difference did not reach significance [t (16) = -1.454; p = .16; d = 0.35] (See Fig. 3A). When correction for the two comparisons is applied (p value of .25), the difference in top face areas becomes a trend. Nevertheless, the percentage of over/underestimation between face halves was significant, [t (16) = -2.42, p = .03, d = 0.59], indicating that the top half of the face is perceived to be significantly shorter than the bottom half.

3.4 Face widths

Five different widths were considered: right eye (i.e. F2 to F3; See Fig. 1B), left eye (i.e., F4 to F5), distance between eyes (i.e., F3 to F4), nose (i.e., F6 to F8), and mouth (F9 to F10). Distances were calculated in centimetres and results were averaged across all participants (as for face lengths; reported in Fig. 3B).

A repeated-measures ANOVA was run with two factors: condition (real versus perceived width in centimetres) and area (the five facial features detailed above). There was a significant effect of condition [F (1,16) = 91.789, p = .001; $\eta^2_{partial}$ = 0.85], suggesting that participants showed an overall distortion of perceived face width. There was also a significant effect of area [F (4,64) = 111.798, p = .001, $\eta^2_{partial}$ = 0.88] and a significant interaction between condition and area [F (2.66, 42.51) = 12.684, p = .001;

$\eta^2_{partial}$ = 0.44] (Greenhouse – Geisser correction), indicating variability in the magnitude of width perception depending on the face area considered. Post-hoc analyses (Bonferroni correction p < .01) showed that all areas were perceived significantly larger than their real size: right eye [t (16) = -6.58, p = .001; d = 1.6]; between eyes [t (16) = -5.91, p = .001; d = 1.43]; left eye [t (16) = -4.293, p = .001; d = 1.04]; nose [t (16) = -7.04, p = .001; d = 1.71]; and mouth [t (16) = -10.44, p = .001; d = 2.53] (See Fig. 3B). However, there were differences in the degree of distortion depending on the face feature considered. This was most apparent for the nose (103.03%), followed by the mouth (70.38%), right eye (64.30%), and left eye (52.81%). Bonferroni corrected t-tests (p value of .008) were run to check if the differences in the degree of distortion where significant between face features. Significant differences were found between the distortion for the nose and all the other face features, indicating that the nose is perceived significantly more distorted than the right eye [t (16) = -3.46, p = .003, d = -0.84]; the left eye [t (16) = -3.51, p = .003, d = -0.85] and the mouth [t (16) = 3.37, p = .004, d = 0.82]. No significant differences were found in the distortions between the other face features.

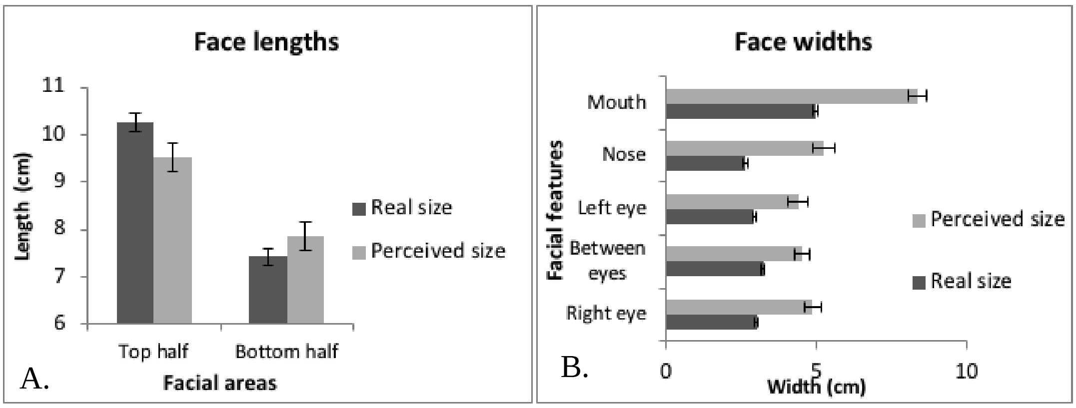

Fig. 3 Face real and perceived lengths (A) and face real and perceived width (B).

4. DISCUSSION

We have assessed for the first time the metric and locational representation of facial features, examining the proprioceptive influences in the structural representation of the face. Our findings confirm our hypothesis that healthy volunteers hold a distorted representation of the face. In particular, structural representation is least accurate for face width. In contrast, length estimation is relatively accurate when considering overall face length. We acknowledge that the method adopted to implicitly calculate the length and width of face structures may have been biased by the misallocation of a single landmark. Therefore, each landmark was requested 6 times to minimize possible bias due to occasional misallocation of a single landmark.

As initially hypothesized, length perception was not unitary and appeared to be compartmentalised into two separate sections: the upper (underestimated) and bottom (overestimated) regions. The compartmentalised representation of face length may be associated with the different functionality and relevance of each face portion, but also with the capacity of facial areas to change size and shape. With the exception of the eyebrows, the upper face areas are relatively stable in size and shape, whilst the bottom areas are subject to more positional changes. During a wide array of daily functions, such as speech or feeding (Cavina-Pratesi et al., 2011; Fuentes et al., 2013), movement of the lower jaw means that the effective size and shape of the lower face is subject to significant changes in position, size and shape. This may lead to a perceived overestimation of its length.

Similar to observations of size overestimation for ankles and wrists (Longo, 2017; Stone et al., 2018), the direction of distortion for the lower face follows the direction of movement. That is, the mouth and chin are perceived lower, shifted towards the body, increasing the perceived length of this region. These findings are consistent with face image studies where this compartmentalisation has also been reported (Fuentes et al., 2013). However, in our study, the overall perceived length is more accurate than previously reported, probably due to the proprioceptive pointing task used here. In fact, increased accuracy in the representation of the body model is also shown for the hands, when vision is removed and participants rely in proprioceptive information instead (Longo, 2014). These results support the idea that proprioceptive pointing tasks show the more implicit representation of the body model, underlying the position sense and allowing us to know the online location of the body (Longo, 2015).

We also found that all face features were perceived to be much wider than their true size, confirming the tendency to perceive the face as wider (D'Amour & Harris, 2017; Fuentes et al., 2013). Width overestimation may be associated with representation in the somatosensory cortex. In fact, Longo & Haggard (2011) postulated a shared implicit representation of the body size and shape, discerned both by touch and position sense, which preserves characteristics of somatosensory homunculus. The cortical representation of face features is also not uniform: for example, the lips occupy a larger region than cheeks (Nguyen, Inui, Hoshiyama, Nakata, & Kakigi, 2005). Our data follows this pattern, finding different magnitude of distortions for different features. The nose was the most overestimated area (103.84%), whilst the left eye was the least (54.29%). Similarly, a recent study in self-face perception (using two-alternative forced choice task with distorted images) has shown how the accuracy to recognise the real size of face features is worse for the nose, followed by the mouth, and lastly by the eyes ((Felisberti & Musholt, 2014). Yet, if somatosensory representation was causing these distortions, we would expect larger overestimation of the lips in comparison with the nose or eyes. A potential explanation for this finding is the *reversed distortion* hypothesis, which proposes that bodily areas with lower numbers of tactile receptive fields are over-represented in a cortical body map in order to compensate for this lack of resolution (Linkenauger et al., 2015). This could explain why in the present data the nose is largely overestimated, as this area is less well represented in the somatosensory and motor homunculi, but it does not explain why the mouth is also perceived larger than its real size.

Other studies in self-perception and size have found biases to identify the self with larger size stimuli (Sui & Humphreys, 2015), which may explain, in part, the tendency to perceive the face much larger than its real size. This self-bias effect has been associated with the emotional and power significance of larger stimuli (Sui & Humphreys, 2015), with strong influences in size perception.

Nonetheless, it is necessary to form a mental image of a body part in order to judge its metric representation (Smeets, Klugkist, Rooden, Anema, & Postma, 2009) and to compare to others too (Walton & Hills, 2012). A particular quality of the face mental image in comparison to the hands is that is constructed secondarily; that is, we only See our face reflected on a mirror, captured in a picture or recorded in a video. Furthermore, the face is normally seen in movement (Tsakiris, 2008), and the stored image of the face may include details of possible movement and its layout, as it occurs for other body parts, such as the hands (Bremner, Holmes, & Spence, 2008) and lower limbs (Stone et al., 2018). To explore this, we analysed the shift of locational responses, which may also explain the direction of the distortions. All face areas were perceived shifted down, closer to the body than they really were. This shift could be due to the stored position of the face, which includes the possibility of movements, shifting responses towards most typical position of the body part.

We also investigated the horizontal shifts of locational responses to consider any differences in the perception of the body in the personal space. Rather than showing a symmetrical representation of the face, there was a predominance to shift responses to right landmarks towards the right hemispace. The rightward shift might be due to the fact that the participants were asked to use the right hand to point. However, if this was the case, we would not have found the leftwards shift for the left eye. This finding seems more in line with previous studies on body space representation, which showed that right-handers tend to overestimate the size of the right portion of the body (Hach & Schütz-Bosbach, 2014). In particular, pointing responses to rightwards areas of the hip and waist were located further from midsagittal plane than left areas, even if pointing was performed with the contralateral hand (Hach & Schütz-Bosbach, 2010). Furthermore, right-handers perceive their right hand and arm to be longer than the left one (Linkenauger et al., 2009). This asymmetry is usually reported in more implicit tasks of body representation, such as the pointing task, but not with more explicit tasks, such as body image (Hach & Schütz-Bosbach, 2014). However, this is a debatable issue and a recent meta-analysis study suggests that facial self-processing may be more related to activity of right hemisphere (Hu et al., 2016) rather than handedness.

Functionality of a body part will also affect its size perception (Linkenauger et al., 2009). Studies have already shown how expertise changes the size of the representation in the homunculus, which is in turn associated with improved size perception (Cocchini et al., 2018).

In summary, our study allows a better understanding on previous self-face perception research, providing a structural metric map of single face features. In particular, this is the first study to investigate self-face representation through first-person perspective pointing, showing implicit characteristics of body representation. Interestingly, the distortions of self-face representation are qualitatively similar to those observed for other body parts when similar tasks are used, suggesting a related underlying mechanism. Further, the proximal shift implies a general shift of perceived body location towards the perceived centre of the self. The explanations considered to account for the distortions of self-face representation emphasise the reliance on a mental image of one's own face based on the combination and mental reconstruction of sensory information, and experience.

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6. DECLARATION OF CONFLICTING INTERESTS

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